A SYNOPSIS ON

CLUSTERING AND CHANGE POINT DETECTION IN WIRELESS SENSOR NETWORKS FOR FIRE DETECTION APPLICATION

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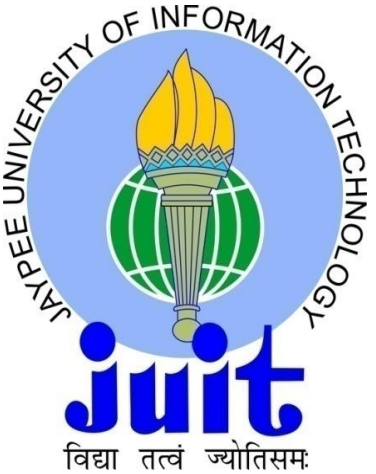

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ABSTRACT

Wireless Sensor Networks (WSNs) are gaining widespread importance day by day. WSNs are having broad categories of applications in every field; from home applications to defense surveillance monitoring; from personal vehicular applications to medical field applications. WSNs have touched everywhere in applicability. WSNs need to fulfill multiple design objectives like Small Node Size, Low Node Cost, Low Power Consumption, Self Configurability, Scalability, Application Specific, Reliability, Fault Tolerance, Security, Channel Utilization, QoS Support etc.

This thesis focuses on two major objectives of WSNs; first is to reduce power consumption for communication in WSN and second is to make WSN more usable for fire detection application. The first objective solved by presenting a solution to reduce power consumption by in WSN and that will further improve network lifetime, and the second objective is obtained by proposing change point detection technique using fuzzy logic for the fire application.

This thesis addresses three concerns related to energy consumption and change point detection a) grouping of WSN nodes, b) routing of data in WSN, and c) change point detection in fire application.

After intense survey it is found that, Clustering is one of the methods to reduce power consumption by grouping of sensors which will improve network life time by saving battery life of sensor nodes. In this thesis we have proposed a new clustering protocol namely Mutual Exclusive Distributive Clustering (MEDC). MEDC protocol selects cluster heads on remaining energy factor. This protocol selects that node as a cluster head which have highest residual energy under that range of communication. MEDC protocol has shown significant improvement in network life time. Further new protocol has been proposed namely Mutual Exclusive Hybrid Energy Efficient Distributive Clustering (MEHEED) which is merged solution of MEDC with most famous protocol Hybrid Energy Efficient Distributive Clustering (HEED) protocol. MEHEED clustering takes advantage of both protocols and shown significant improvement.

To solve the second objective of our thesis we have proposed fuzzy logic based change point detection technique for fire application. We have proposed the approach for detecting the change at cluster head level. This approach uses MEDC protocol for selecting cluster heads. Change point detection will be applied on cluster head using fuzzy logic. Fire detection application is considered to show change point detection. It is assumed that sensors will sense three parameters heat index, relative humidity, and carbon monoxide. Cluster heads sensor nodes which are chosen by MEDC will collect sensory inputs from member's nodes and aggregate these sensed parameters. Based on the aggregated values fire detection will be performed using fuzzy logic approach on cluster heads.

CHAPTER 1
INTRODUCTION

1.1 Wireless Sensor Networks

Wireless Sensor Networks are gaining wide-reaching consideration in recent years. Wireless Sensor Networks are constituted with tiny electro mechanical devices i.e. sensors nodes. Sensor nodes communicate via RF signals with one or more powerful sinks called base stations (BSs) shown in figure 1. Communication can be called single hope if they can contact directly to base station; or can be Multihop communication in which intermediate nodes in path from sensor node to base station. Formally sensor networks on basis of their functionality are classified into two types one is proactive and the other is reactive networks. Proactive networks are passive in nature and well suited for data aggregation type applications. In this type of networks nodes sense and send data on periodical basis i.e. on regular intervals. In Reactive networks, opposite to passive networks sensor nodes respond immediately and only to changes in the relevant parameters of interest. Reactive networks are more suitable for time critical applications. To prolong lifetime of sensor networks it will be more efficient if sensor nodes can collaborate with each other. That is the reason why sensor networks need management planes. As per requirement three management planes will work which are named as power management plane, mobility management plane, and task management plane [Akyildiz, et al., 2002]. Wireless sensor Networks are growing their interest day by day. WSNs have applications in various fields like medical, military, weather forecasting and many more [Ameer Ahmed, 2007].

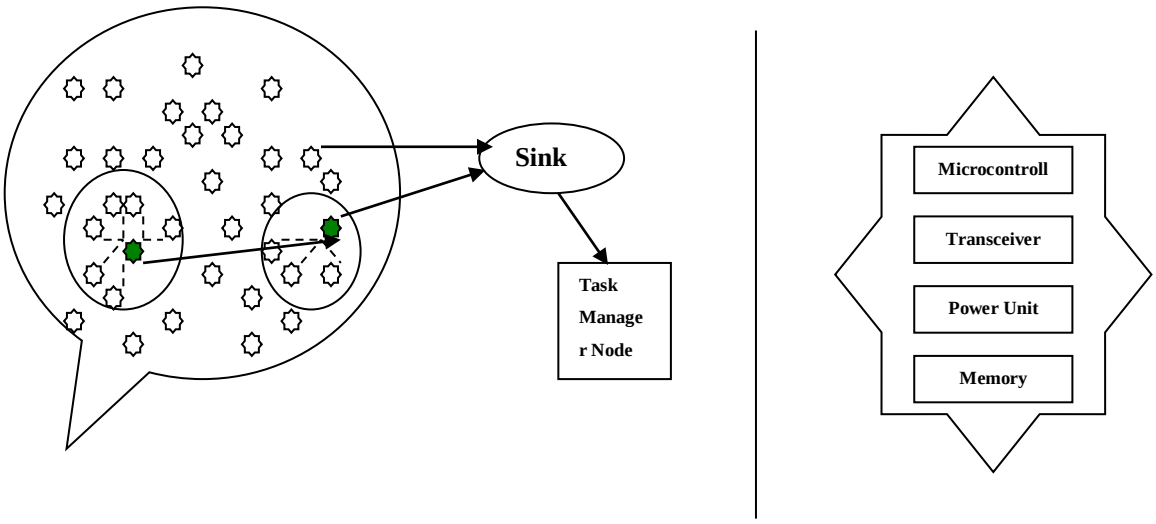


Figure 1. Wireless Sensor Networks

Each sensor node is packed unit of Microcontroller, Transceiver, power unit and battery. *Microcontrollers* are like tiny computer. Sensor uses microcontroller who can have 8 to 128 pins. They run on 3.3 to 5 Volts and can works with frequency 8 to 20 MHz. usually they have 256 bytes of RAM. *Transceiver* used for communication between nodes and base station. The two major functions of *Transceiver* are transmitting and receiving.

Transmission media is usually RF signals but sometimes they also use license free range of communication 173, 433, 868, and 915 MHz and 2.4 GHz. Sometime Transceivers have additional feature that they can posses any of these four states i.e. Transmit State, Receive state, Idle state, Sleep state. *Power* source of sensors are form of batteries or capacitors. And last part is M*emory* unit for storage usually sensors have storage in KB, Flash Memory, RAM etc. One of most challenging fact in WSN is limited battery power of sensors. With this limited battery power, sensor performs three tasks which are sensing, representing the sensed information and third is Transmitting/ Receiving. Out of these three, transmissions are most energy consuming task. Literature says that transmitting k bits to a distance d, the power requirement is proportional to d^2 or d^4 depending on free path or multipath. To save battery life multiple ways had been proposed and worked in research; Clustering is one of those.

1.2 Genesis of Problem

Wireless Sensor Networks (WSNs) are gaining widespread importance day by day due to its broad categories of applications in every field; from home applications to defense surveillance monitoring; from personal vehicular applications to medical field applications etc. As most applications require a long network lifetime but challenges like tight energy constraints, high density WSNs are critical. In case of high density WSN will turn off few nodes but remain operational as well. The point to note is that WSNs have touched every field in applicability therefore it needs to fulfill multiple design objectives as well like Small Node Size, Low Node Cost, Self Configurability, Scalability, Reliability, Fault Tolerance, Security, Channel Utilization, QoS, Low Power Consumption, and Application Specific needs etc. also it can be said WSN should be challenged to efficiently handle some of the trivial issues like power consumption, network life time and to prove themselves application specific like change point detection. Out of several issues limited battery power or to save battery power aimed to make network more sustainable is the crucial one. Many energy saving techniques were in discussion among them Clustering is most fancy one. Clustering techniques solve multiple objectives along with power economy. The centralized clustering protocols face disadvantage of high powered base station requirement. It is also found that distributive protocols work on residual energy factor but residual factor is not directly considered infect most famous protocol has also used this factor for probability calculations. Why not Distributive protocol can directly consider residual energy factor only? Which method should sensors follow to select cluster heads if residual energy is only criteria?

Clustering can reduce power consumption by reducing data on communication. It is also a well understood concept that event detection in WSN also has less data communication requirements. So merging these two concepts i.e. clustering and change point detection together can produce more sustain networks which can have better life time. Up to best of our knowledge no clustering protocol has done work on this. Work can be done on energy consumption and change point detection together.

1.3 Problem Statement

The motto of this research work is to propose protocols that are energy efficient and those can support change point detection or event detection. Sensor nodes use their battery for detecting and collecting information from the region of deployment but the hard fact is there very little scope for recharge or change batteries of sensor nodes. These sensing nodes collect and pass the information from the network towards the base station for

further actions. We need to consider energy consumption as a major factor of concern for a better functioning and a longer life timed network. In literature, many authors have contributed toward grouping of sensor nodes and routing the information in WSN. But best of our knowledge none off clustering protocol has targeted on change point detection application as well.

1.4 Objectives

The following objectives corresponding to the problem statement have been achieved in this work.

a) To group the sensor nodes in WSN for reducing the power consumption in communication for improving network life span of WSN.

b) To design a new clustering protocol which should be energy aware by which energy efficiency could be improved.

c) To design and develop change point detection scheme for fire detection application in WSN.

Mapping these objectives onto WSN, the following three distinct intended deliverables have been achieved:

I) Mutual Exclusive Distributive clustering (MEDC) protocol proposed. This result following points

- i) Cluster Formation
- ii) Network lifetime improvement

II) Mutual Exclusive Hybrid energy Efficient Clustering (MEHEED) protocol proposed. This result following points

- i) Cluster Formation.
- ii) Include benefits of HEED protocol as well.
- iii) Further Network life time improvement in contrast of MEDC.

III) Change Point Detection along with MEDC protocol (using Fuzzy Logic) which results

- i) Fire Detection

1.5 Approach followed

To develop new clustering protocol distributive approach is firstly considered. Distributive approach leads to each sensor node to participate in cluster heads selection. Each sensor node will advertise residual energy. On based of message passing system nodes with highest residual energy will be selected as cluster heads in their range of communication. Based on this approach we proposed MEDC protocol.

Further to improve efficiency of MEDC clustering protocol HEED's protocol logic was combined with it and a new protocol was proposed MEHEED. MEHEED takes advantage of MEDC and HEED. MEHEED will firstly select those sensors as cluster heads that are having probability equal to one without considering residual energy and without floating advertisements. In case if no sensor node under range of communication is having probability equal to one in that case MEDC logic will be used and sensors will decide their cluster heads to that sensor that is having highest residual energy. Advertisements will be float in this case only Benefit of MEHEED is it showed better performance in improvement of network lifetime contrast to MEDC.

For Change point detection we had chose fuzzy logic approach. Reason for choosing fuzzy logic is it can fuzzify crisp value to fuzzy sets of real scenario. After fuzzify input values fuzzy rules can map to inputs toward

outputs. The point of using FIS (Fuzzy Inference system) is that it can show fuzzy output to crisp value after Defuzzification.

1.6 Contributions

(i) Mutual Exclusive Distributive Clustering (MEDC) protocol has been developed. The work assumes that each sensor node is having equal capabilities and they are having non rechargeable battery. MEDC protocol floats advertisements and decides cluster heads in distributive manner (each sensor participates in selection process). This protocol selects that node as a cluster head which have highest residual energy under that range of communication. MEDC protocol has shown significant improvement in network life time.
(ii) Mutual Exclusive Hybrid Energy Efficient Distributive Clustering (MEHEED) has been developed. MEHEED is merged solution of MEDC with most famous Hybrid Energy Efficient Distributive Clustering (HEED) protocol. MEHEED clustering takes advantage of both protocols and shown significant improvement. The reason for betterments of MEHEED is that it will try to select cluster heads firstly on probability basis. Message floating will be done only when there is no sensor node from range of communication is having probability equal to one
(iii) A fuzzy logic based change point detection technique for fire application has been developed, which detects the change at cluster head level. This approach can also have positive impact in saving energy; because cluster heads will transmit only when they found more then 50% chances of any event from aggregated inputs

1.7 Thesis Layout

Thesis work is organized into five chapters. First Chapter is about introduction to WSN, Clustering and Change Point Detection. Introduction includes basic terminology related to these topics as well. Second chapter presents intense survey related to thesis work. Literature survey covers research history and trends of evolution of WSN. This chapter includes existing clustering protocols. We had tried to present tabular summery of clustering protocols on feature basis. Next part of this chapter presents literature survey under different change point detection methods. Third Chapter is our first contributory work named MEDC protocol. This chapter presents introduction to MEDC protocol, its algorithm and its results under various parameters. We had presented examples to show working of MEDC protocol. Simulation for MEDC is done on MATLAB. For evaluation of this clustering protocol network lifetime criteria is taken, Results of MEDC are compared with HEED; and it is shown that MEDC is performing better than HEED. MEDC protocol has shown improvement in network life time. We had also shown performance of MEDC under various parameters. Forth chapter is about our second contributory work named MEHEED. MEHEED protocol is merged solution of two clustering protocol one is MEDC and the other is HEED. This chapter will first present concept of MEHEED clustering protocol then algorithm after that experimental results under various parameter. Performance of MEHEED is compared with MEDC and HEED as well. Fifth chapter introduces Fuzzy Inference System (FIS). Then it will show our third contributory work i.e. change point detection for fire detection scenario. FIS will be input with three parameters and output will be fire probability. Thesis ends with chapter six which is about conclusion of thesis work and future work possible

CHAPTER 2
WIRELESS SENSOR NETWORKS: LITRATURE REVIEW

2.1 Introduction

In 2002 Akyildiz presented five layered architecture along with three management planes of wireless sensor networks [Akyildiz, et al., 2002]. Author has discussed wide range of applications and some factors like scalability, mode of transmission, fault tolerance, hardware limitations, topology and power consumption which can affect design of wireless sensor networks. Survey also says that, sensor networks are different from Adhoc network so Adhoc routing protocols are not useful for WSN. The reason for this mismatches or can say applicability difference, is *energy constraint* of sensor networks. This is worth to understand that sensor nodes are limited in battery life. So it's is very important to concentrate on energy saving of sensor networks. Number of concepts for energy saving has been discussions; clustering is one of them. Next in 2003 Chong, et al. [Chong, et al., 2003] have explored history of research in sensor networks over the past three decades. Paper give review how sensor network started from Military Sensor Networks in 1890 and proceeded at next level in form of Distributed Sensor Networks to current 21st century. Paper has presented several new applications like infrastructure security, industrial sensing, environment surveillance and traffic control etc and also discussed technological trends and challenges that impact development of Wireless Sensor Network. Trends of evolution in Wireless Sensor Network are given by Benini, et al. [Benini, et al., 2006]. Additionally, they categorize Wireless Sensor Network in four different generations (obtrusive, parasitic, symbiotic and bio-inspired) and discuss key research challenges in Wireless Sensor Network together with current developments, node architecture, and hardware technology for future directions. In 2007 author Baronti had presented [Baronti, et al., 2007] a new standard IEEE802.15.4 name given by Zig Bee. IEEE802.15.4 is standard name given to Low-Rate Wireless Personal Area Networks (LR-WPAN).Authors had overviewed sensors hardware first then introduced 802.15.4 after which authors worked to present MAC layer and Network layer protocols for this standard along-with various performance characteristics for IEEE 802.15.4 and have concluded with the future trends of Wireless Sensor Network. Yick, et al. [Yick, et al., 2008] have presented more recent literature survey of Wireless Sensor Network including key issues in Wireless Sensor Network at node level as well as at group level. They have also surveyed recent issues like localization, network security, data aggregation, compression, coverage and presented a number of research issues for Wireless Sensor Network. Under networking one interesting topic data aggregation has used cluster approach of communication. Clustering is approach to save communication energy. We will discuss this topic in detail later. Further in 2009 author Burratti had done one more survey on WSN and presented different design requirements according to applications in [Buratti, et al., 2009]. Paper has presented a case study on environment monitoring. Standard IEEE 802.15.4 which was introduced in [Baronti, et al., 2007] motes are used for case study. Author has clearly shown that regular monitoring without panel uses more battery power; so battery drained out very fast. Here we also concluded that regular monitory uses more battery power then it can be said that event detection will definitely reduces power consumption. From here we get a new objective will be event detection instead of regular data gathering.

2.2 Clustering

In 1997 author Lin has proposed cluster based architecture in WSN. In the proposed network architecture, nodes are organized into non overlapping clusters which are independently controlled [Lin , et al. , 1997]. It's a grouping of sensors in such a way that one sensor will become cluster head and others will be cluster members. Objective of clustering algorithm is to divide network into clusters to support Multihop communication and to support QoS. This paper has evaluated clustered network in terms of connectivity, transmission range and end to end throughput. Further in 1999 Estrin, said Clustering can contribute to more scalable behavior as number of nodes increase, improved robustness, and more efficient resource utilization for many distributed sensor coordination tasks [Estrin, et al, , 1999]. Clustering comes under scalable network protocols. Clustering can also take as implementation of hierarchical networks.

First Clustering protocol was proposed by Heinzelman in 2000 [Heinzelman , et al., 2000] later modified in [Heinzelman, et al., 2002]. LEACH protocol works in two phases Setup Phase and Steady phase. LEACH is a distributive protocol; it selects cluster heads on probability basis. LEACH also ensures that no cluster head will be repetitively chased. At the starting level of LEACH, each member is assigned with the equal probability of being a cluster head cluster members are compared with the threshold value, or they are compared with their previous experience of being a cluster head. After the end of single iteration, the winner cluster member is selected as cluster head. Each non-Cluster head node determines its cluster by choosing the Cluster Head that can be reached using the least communication energy. This algorithm runs in iteration and in successive iteration cluster heads are reechoed. In 2001 [Manjeswar, et al., 2001] TEEN (Threshold sensitive Energy-Efficient sensor Network) is distributive power base protocol. It was developed for reactive networks. Reactive networks are those networks in which sensor nodes keep sensing but transmit only when they find any change value from threshold value. Protocol works by taking two values; one is a hard threshold and other is a soft threshold. The sensor nodes keep sensing data but transmit data only when both the conditions are true; out of two conditions one is when the current value of the sensed attribute is finer than the hard threshold, and the second is when the current value of the sensed attribute differs from SV by an amount equal to or finer than the soft threshold. This protocol is best suited for time critical application, for example, all applications where change point detection is required.

Further in 2004 author Younis has proposed Hybrid Energy-Efficient Distributed clustering (HEED) in paper [Younis, et al., 2004]. HEED protocol is again distributive I nature and also power base protocol. Another distinguish feature of HEED is that it's a multilevel clustering protocol which also support multi hop communication. HEED protocol periodically selects cluster heads according to a hybrid of the node residual energy and intra-cluster communication cost. HEED has an advantage that it does not require special node capabilities, such as in HEED, location-awareness, does not depend on node distribution *etc.* In HEED, each node is mapped to exactly one cluster and can directly communicate with its CH. The algorithm is divided into three phases: first one is initialization phase, second one is repletion phase followed by third phase that is finalizing phase. In 2005 author Li has proposed one more distributive clustering protocol which also supports multi hope Inter cluster communication which named as energy-efficient different clustering protocol (EEUC) in [Li, et al. , 2005]. EEUC works differently as it divides the nodes into clusters of unequal size of sensors. Cluster partition is done on the basis of distance from the base station. The clusters closer to the base station have smaller sizes and consume less energy for data forwarding than those farther away from the base station.

This protocol has showed good performance in terms of throughput. In [Yi, et al,, 2007] Power-efficient and adaptive clustering hierarchy protocol (PEACH) has been introduced . PEACH is multi-level clustering, which can be used for both location-unaware and location-aware wireless sensor networks. This protocol removes the difficulty of cluster formation. Location-unaware PEACH protocol operates in fully distributed manner. Author Yang has invented a centralized protocol named as SHORT in [Yang , et al. , 2007]**.** It is a centralized chain based protocol in which clusters have to be selected by base station that is reason why it requires high-power base station. The author showed performance results of SHORT that it can achieve better energy to delay performance than the existing chain based data aggregation protocols. But this is well understood fact that centralized protocol is having limitation of high power base station requirement. Again one more distributive protocol was in work, proposed by author Lung in 2010. DHAC is a distributive hierarchical multilevel agglomerative clustering proposed in [Lung, et al., 2010]. It is actually an extension to work done on HAC. The author in this paper has been simple in defining six-step clustering in which the work is done by grouping similar nodes together with the help of a resemblance matrix. The main idea behind DHAC is that a node only needs knowledge of one hop neighbor to build clusters. DHAC avoids re-clustering and achieves uniform energy dissipation through the whole network. Author also showed its implementation on NS2 simulator. We are presenting survey of clustering protocols in tabular manner in Table 1.

Table 1- Clustering protocols/ Feature survey

Clustering Protocol	**Centralized**	**Distributive**	**Multi hope Inter cluster communication**	**Location Awareness**	**Power Base**	**Multilevel Clustering**
LEACH		√				
HEED		√	√		√	√
LEACH-C	√			√	√	
TEEN		√			√	
PEACH		√		√		
SHORT	√					
EEUC		√	√			
DHAC		√				√
EECF		√	√		√	
PADCP		√	√		√	
SEECH		√			√	

2.3 Change Point Detection

Change point detection is important in various real-life applications like in environmental monitoring, Habitat monitoring, Health and medical monitoring, Industrial monitoring, Target tracking and Surveillance monitoring etc. Change point theory is also applied in security fields. In WSN one more term 'Outlier detection' is also used in place of change point detection. Term Outlier is first introduced in paper [Hawkins, et al., 1980]. Hawkins said *an outlier is an observation (or subset of observations) which appears to be inconsistent with the*

remainder of that set of data. Later term outlier was also discussed for statistical data by Bamett. Author defined *an outlier is an observation, which deviates so much from other observations as to arouse suspicions that it was generated by a different mechanism* [Barnett, et al., 1994]. Later which change point detection i.e outlier has become important in multiple fields. Change point topic was overviewed with TEEN protocol according to which sensors will react only when an event occurs or when change is above to threshold values. Here we will present our survey related to change point detection on methods bases. Change point detection can be done via different methods as shown in figure 2.

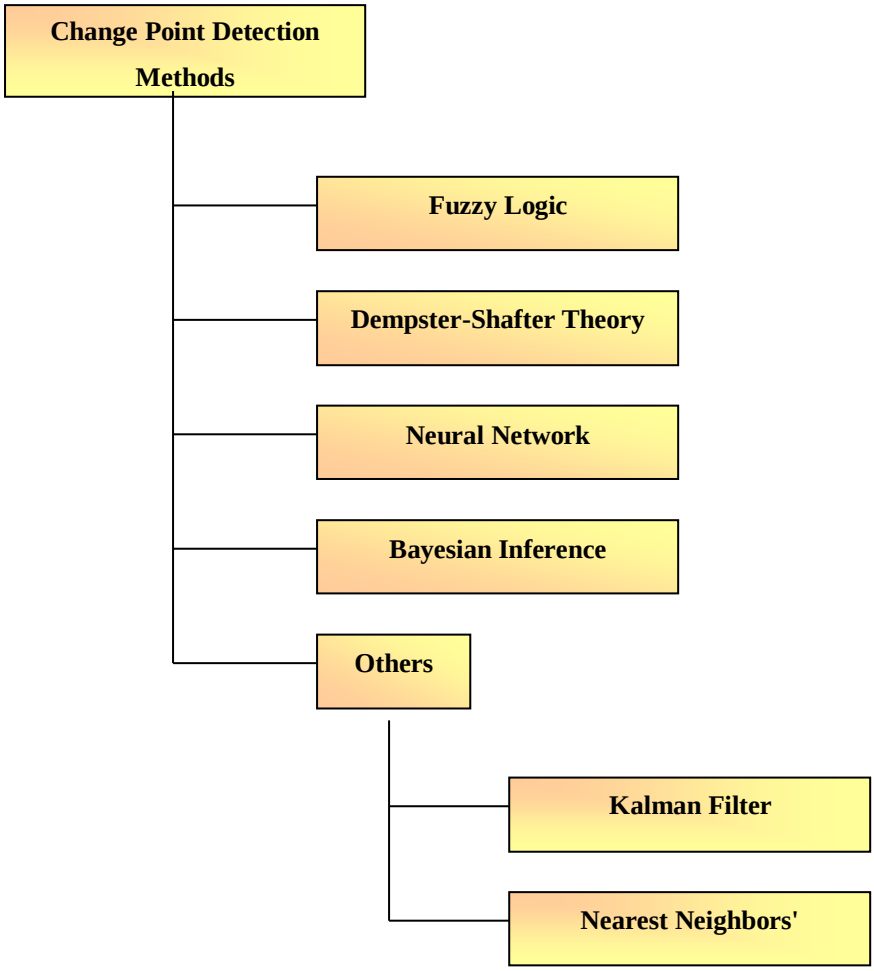


Figure 2. Different Methods for Change Point Detection

2.4 Fuzzy logic

Fuzzy logic is useful method for change point detection method as it starts with imprecise data, build fuzzy sets and fuzzyfied them from probability function for concluding result from fuzzy rules. In 1999 author Metternicht has used the concept of fuzzy sets and fuzzy logic for computation of changes occurred in remotely sensed area for map revision [Metternicht, et al., 1999] The author has formulated fuzzy sets and fuzzy rules for defining the likelihood of changes detected from remotely sensed data then after they used decision support system to conclude change. Authors had shown that fuzzy logic has given better change detection results in contrast of traditional systems like image ratio etc. results are shown to prove how change point detection using fuzzy theory help to conclude map revision more accurately. In paper [Zlokolica, et al., 2005] author had worked on

application concerned on tracking and denoising of image sequence. The work has contributed fuzzy recursive motion detector. The author has worked by inputting noisy sequence with fuzzy logic motion detector in order to determine the degree of motion confidence. They proposed motion detection algorithm; concentrating on two criteria one is robustness to noise and second is changing illumination conditions and motion blur in temporal recursive denoising. Further in 2011 the author D'Angelo used fuzzy logic for fault detection problem in induction machine stator-winding [D'Angelo, et al. 2011]. They used change point detection in time series for better prediction of the new failure detection procedure against false alarms, combined with a good sensitivity that allows the detection of rather small fault signals. They had defined and implemented two steps procedure. First step is transformation of initial data using fuzzy clustering. Second is change point detection with the help of Metropolis–Hastings algorithm.

2.5 Conclusion

- Out of many energy aware clustering schemes none has used updated energies of sensors like in LEACH remaining energy had been used to find probability only in setup phase.
- Some clustering protocols are taking cost of communication but like in HEED Snbr is considered once in initialize phase.
- No combined application oriented clustering protocol has been introduced. Only TEEN protocol has combined clustering with change point detection; but this was only for reactive networks.

CHAPTER 3
MUTUAL EXCLUSIVE DISTRIBUTIVE CLUSTERING (MEDC)

3.1 MEDC

Clustering is groping of sensors aimed to save energy. MEDC will group sensor on basis of mutual exclusion algorithm. In MEDC protocol the Cluster heads will be chosen in a mutual exclusive way over a range of communication. Under a range of communication (says R_c), only a sensor that's having maximum of residual energy will be the cluster head. MEDC will start working with network model assumptions listed as

- Sensor nodes have the same capabilities and resources like battery power etc.
- The data sink is located far from the sensing field. Sensor nodes and data sink are all stationary after deployment.
- Sensor nodes are location–unaware that means they are not equipped with GPS or other similar equipment.
- Periodically the recently sensed data and information by all nodes are gathered and sent to the data sink after aggregation.
- Each sensor node is assigned a unique identifier (ID).
- The links are assumed to be symmetric.

Radio Model-Energy Equations

- Sensors decay their energy on transmission and receiving.
- If there are k bits to transmit over distance d
    - Transmission Energy Dissipation
        - Etx (k) =k* Eelec. + Etx_amp (k, d) (3.1)
        - Etx_amp (k, d) = k*d^2*Efs [9,10] (3.2)
- If sensor is receiving k bit
    - Receiving Energy Dissipation
        - Erx (k) = k* Eelec (3.3)

The proposed protocol will run in iterations, each iteration follow four steps and the cluster head will be reechoes in succeeding iteration. Under R_c, the Cluster head sensor node will be decided on factor of remaining energy. Sensor node which one is having highest remaining energy among the sensors node under R_c will be chosen as cluster head. The idea of Mutual exclusion works by message passing system we will say it by advertisements. Why we are considering the remaining energy factor , is because sensor's remaining energy will be different for each sensor nodes infect it depend on how much each sensor node spends energy for sending and receiving advertisements up to last iteration. Which in turn how much advertisement depends on how many sensors were under range of communication (R_c).

Here we want to explain reason for considering residual energy parameter not distance from base station. Sensors are deployed in local region say in 500* 500 meters; base station is far away say at 25 Km. so relative distance for all sensor nodes will be same for all sensors. As shown in figure 3 for two sensor nodes. Secondly here we consider communication is multi-hop so in between relay nodes will be there so relay nodes will forward the data without consideration from which sensor they are receiving data for forwarding. The third point is that we cannot burden nearly located nodes for relay service in that case they deplete their energy and cause portioning of network problem.

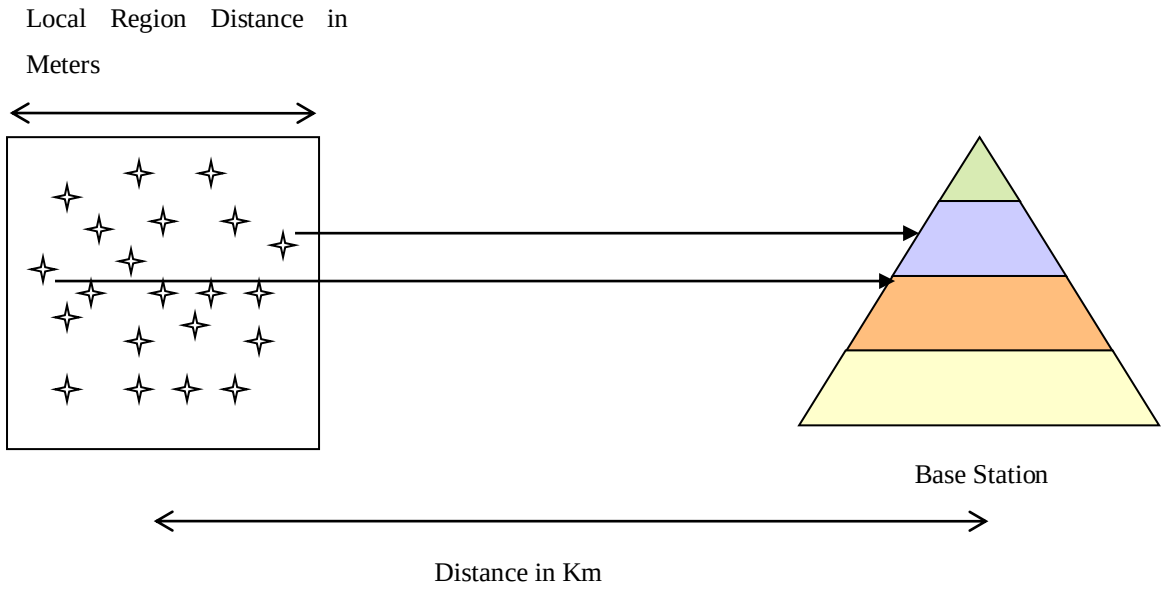


Figure3- Scenario sensors at relative distance from base station

Steps of MEDC algorithm are as follows:

Step 1

Sensors nodes will advertise their remaining battery power to the sensors under range R_c. All sensors nodes will send and receive advertisement. Sensor nodes will maintain a queue for incoming advertisements.

Step 2

All sensors nodes will check their queue. Sensors node send OK message to only those sensors from queue those are having remaining energy more than its own remaining energy. This step also gives clarity that if any sensor node (say IDi) is sending OK message to any of other sensor node (say IDj) which one is having higher remaining energy then presently there is no chance for IDi for becoming cluster head within its R_c. one more point is if a sensor node got advertisement from other sensors those are having power less than or equal to its own power then it will wait up to some period of time.

Step 3

In step 3 after pass of one TDMA slot; each sensor will look up its own status. If the sensor had not sent the OK message to any other sensor that means presently itself is having higher residue battery power. So it will send a declaration message of becoming cluster head to every sensor under range R_c.

Step 4

Cluster head sensor nodes will collect and aggregate data from cluster members under R_c. Cluster heads will transmit the aggregated data to sink node. Cluster head rotation will be done in next iteration. Next iteration starts from step 1.

3.2 Algorithm MEDC

IDi : ID of node i.
R_f : Radius of frequency/ Range of communication.
Qi : Queue of sensor i.
Epresent_i : Present energy of node i.
Procedure Cluster_formation(n)

```
1.      For each Next iteration
2.      For each IDi
3.              Counter =0
4.      For each IDj within Rf of IDi
5               Advertise Epresent_i
6.      For each IDi
7.              Put all incoming advertisements from sensors j into Qi
8.      For each IDi
9.              While Qi is not empty
10.                     If Epresent_i <= Epresent_j
11.                             Send ok message to IDj
12.                             Counter = 1
13.                     Else
14.                             Delete this advertisement from queue
15.     For each IDi
16.             If counter =0
17.                     Send cluster_head_declaration message to IDj within Rf
```

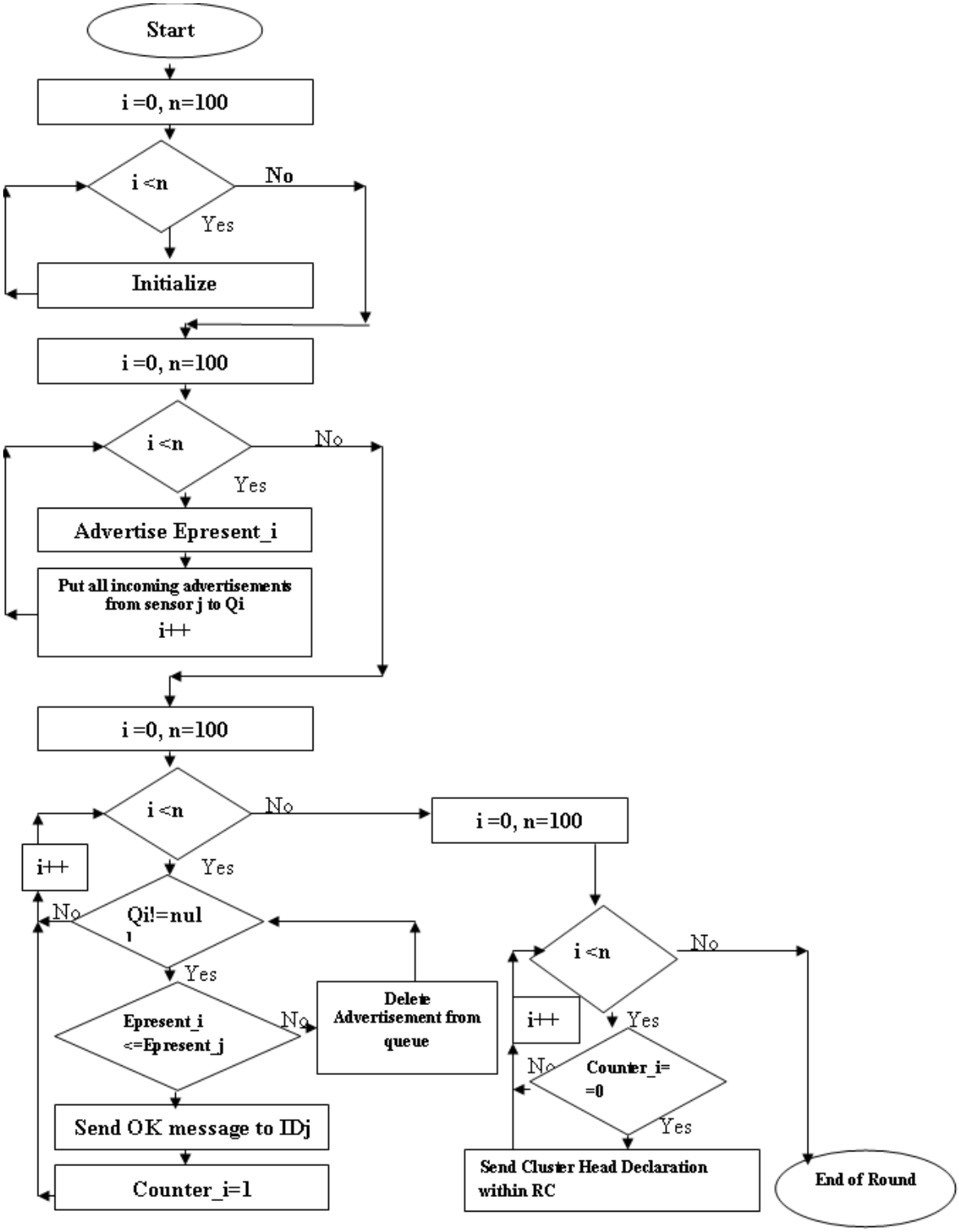
3.3 Experimental Evaluation

For simulation of MEDC on MATLAB we had taken following parameters. Shown In table 2. Results are shown from figure 3 to figure 14

Table 2- Simulation parameters for MEDC

Parameters	**Abbreviation**	**Values**	**Units**
Random field x axis	Xm	100	Meters
Random field y axis	Ym	100	Meters
Initial energy of sensor	Eo	0.05	Joule
Total number of sensor	N	100	
Transmission energy	Etx	50*1.E-12	Joule per bit
Receiving energy per bit	Erx	50*1.E-12	Joule per bit
Free space energy per bit	Efs	10*1.E-12	Joule per bit
Data aggregation energy	EDA	5*1.E-12	Joule per bit
Advertisement energy	Eadv	50*1.E-12	Joule per bit
Range of Communication	RC	20	Meters

3.4FlowChart



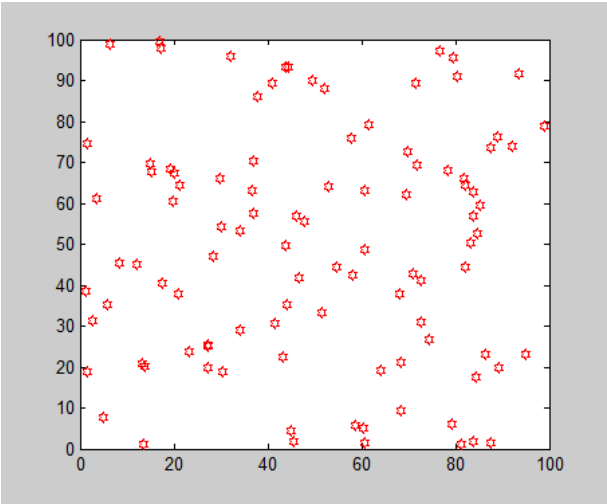


Figure 4. Initial Deployment of 100 Sensors

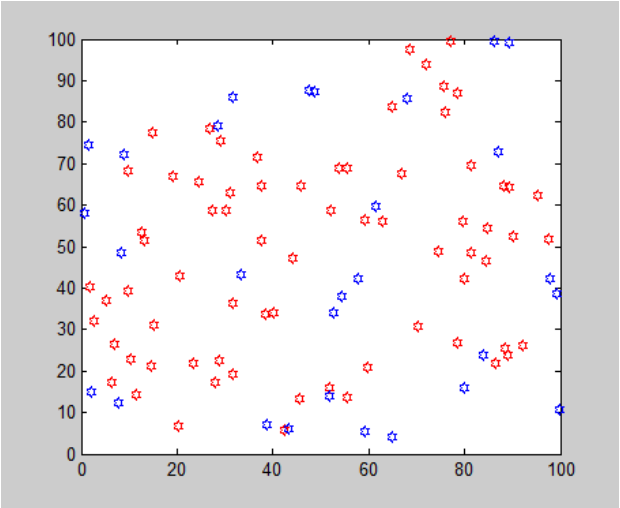


Figure 5. Sensor with Cluster Heads

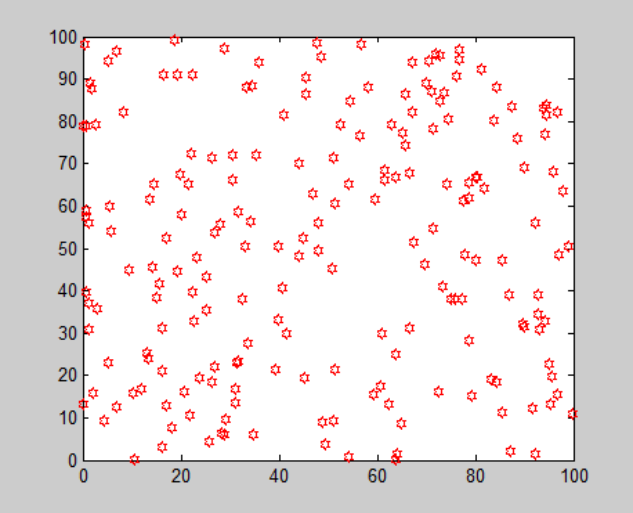


Figure 6. Initial Deployment of 200 Sensors

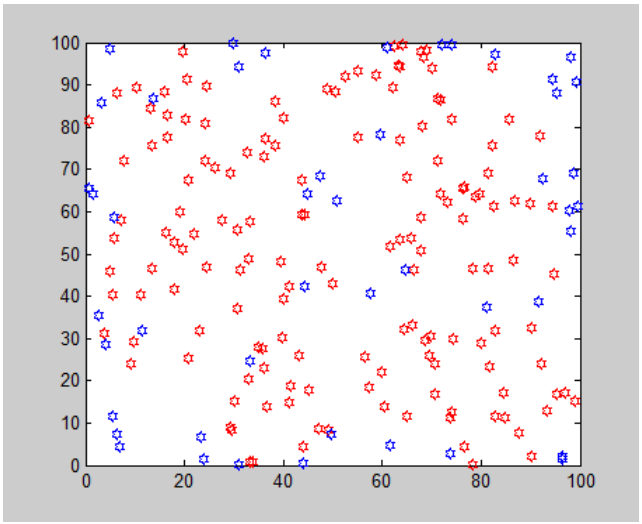


Figure 7. Sensor with Cluster Heads

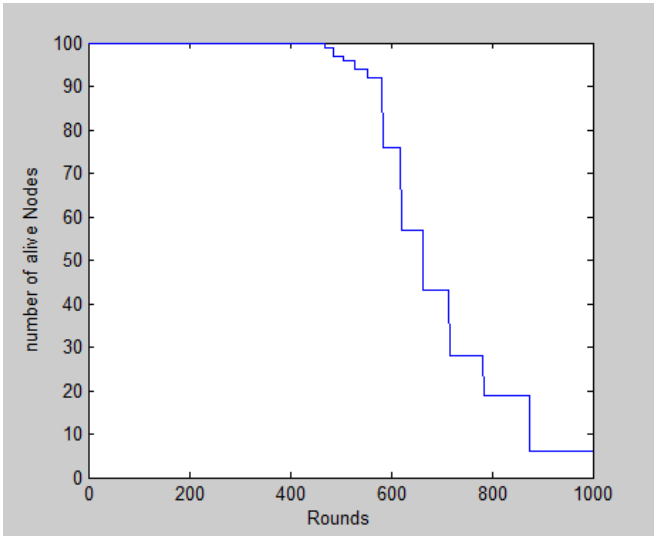


Figure 8. Performance of MEDC when no of sensors are 100 and Rc is 20

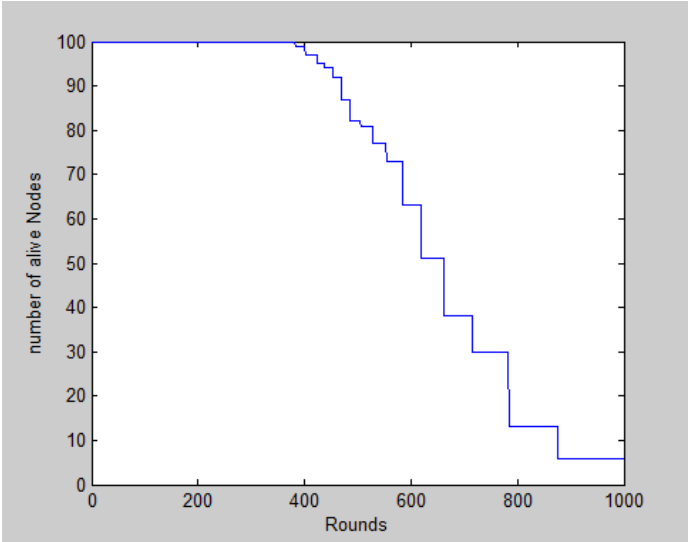


Figure 9. Performance of MEDC when no of sensors are 100 Rc is 40.

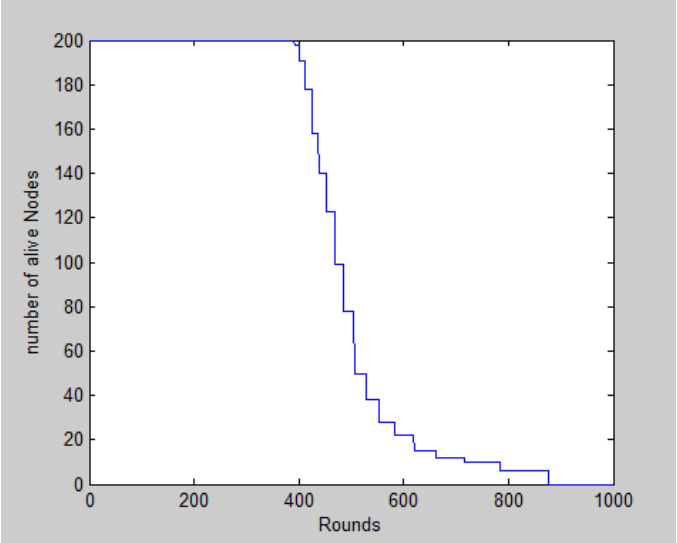


Figure 10. Performance of MEDC when no of sensors are 200 and Rc is 20.

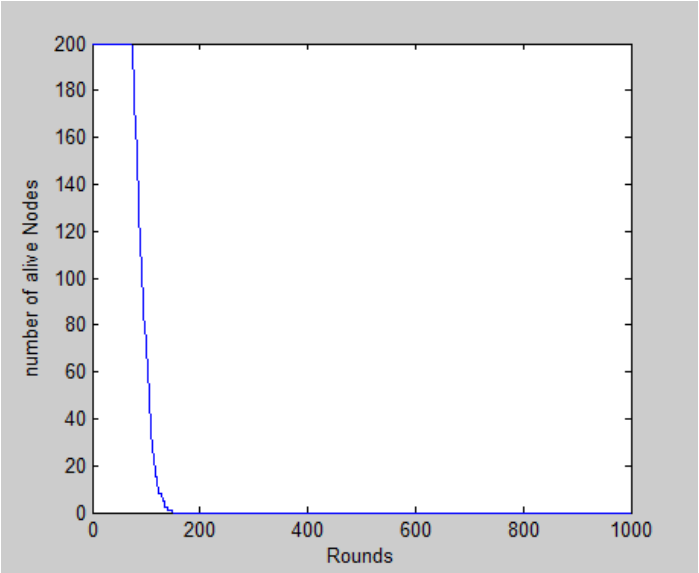


Figure 11. Performance of MEDC when no of sensors are 200and Rc=40

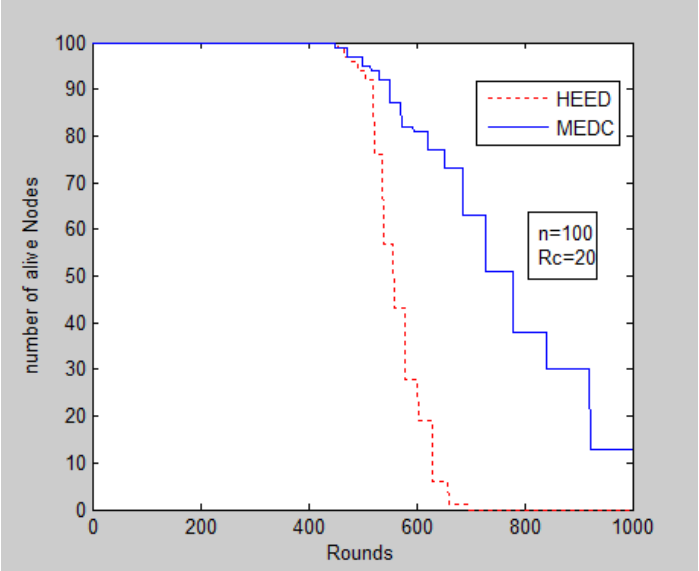


Figure12. Comparative Results of MEDC and HEED number of sensors are 100 Rc is 20

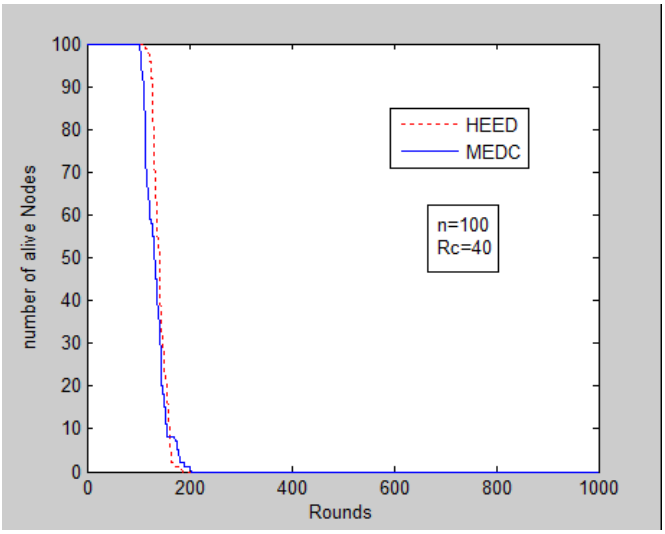


Figure 13. Comparative Results of MEDC and HEED number of sensors are 100 Rc is 40

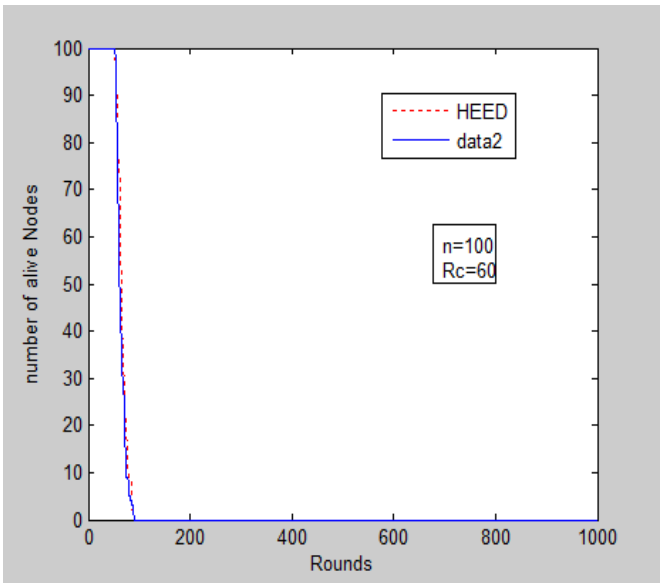


Figure 14. Comparative Results of MEDC and HEED number of sensors are 100 Rc is 60

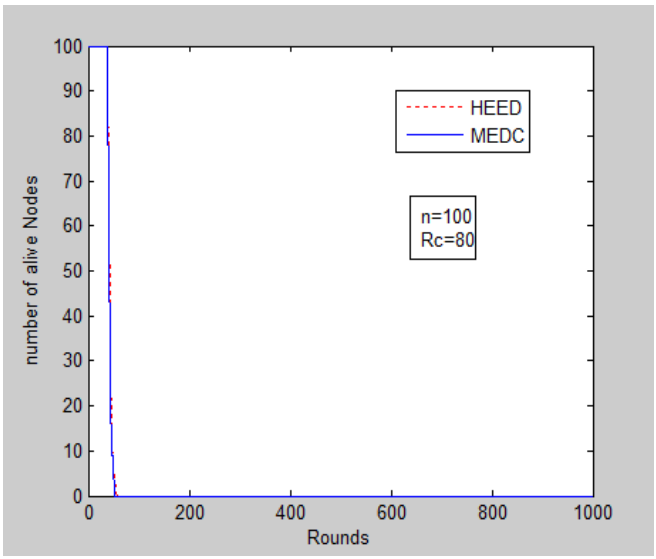


Figure 15. Comparative Results of MEDC and HEED number of sensors are 100 Rc is 80

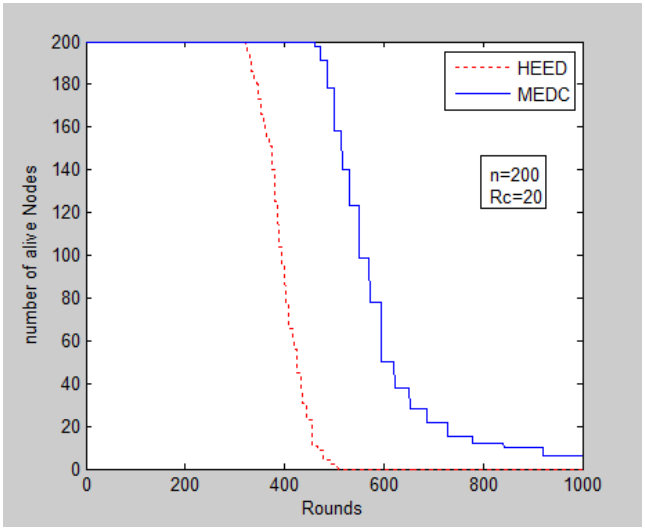


Figure 16. Comparative Results of MEDC and HEED number of sensors are 200 Rc is 20.

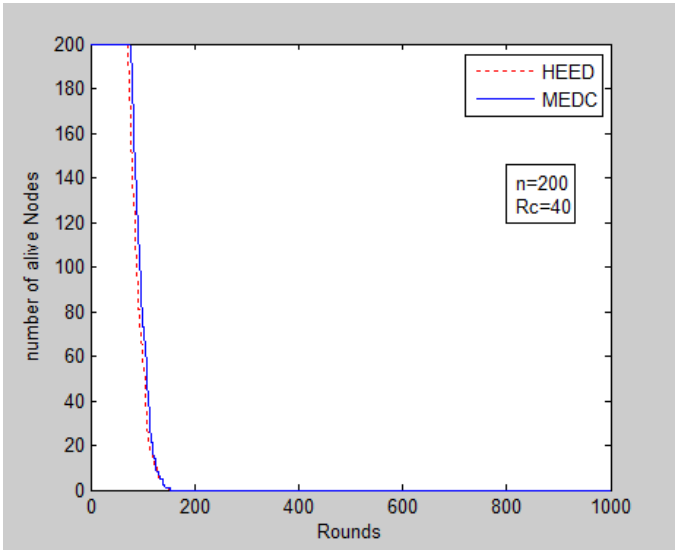


Figure 17. Comparative Results of MEDC and HEED number of sensors are 200 Rc is 40

3.5 Results and Discussions.

MATLAB results of MEDC are given from figures3 to figure 14. Figure 3 is shown result for initial deployment of one hundred sensors over a field. Random function is used for deployment. Figure 4 is result of MATLAB shown here for scenario when some sensors under their range become cluster heads. Blue nodes are cluster heads and red nodes are sensors which will act as cluster members under clusters heads from their range of communication. Figure 5 and figure 6 are results same as like 3 and 4 respectively but now n (number of sensor nodes are 200). Figure 7 is shown for performance of MEDC on parameter n=100 and range of communication is taken as 20. Performance is measured in terms network life time. Network life time is measured as number of alive nodes per round. In result graph Y axis represents alive nodes and X axis represents rounds. Figures 8, 9, 10 are performance analysis of MEDC by varying values of n and Rc (Range of communication) n is varied on two values 100 and 200. Rc is also varied by two values one is 20 and another is 40. Figures 11-14 are comparative results of MEDC with HEED. It is concluded from results that MEDC works better in contrast of

HEED. On parameters n=100 and Rc=20 it gives 33.3 improvement in network life time. As parameter are changed, graph of MEDC come close in performance to HEED. Reason for this decrement in graph is increase cost of communication. When we increase n from 100 to 200 or Rc from 20 to 40 then their will be more no of sensors under range of communication to each other. More sensors under range more advertisements means more cost of communication which result decrease in performance.

CHAPTER 4

MUTUAL EXCLUSIVE HYBRID ENERGY EFFICIENT DISTRIBUTED CLUSTERING (MEHEED)

4.1 MEHEED

MEHHED is extension Work of the MEDC. The network model assumptions for MEHEED are listed as

- Sensor nodes have the same capabilities and resources like battery power etc.
- The data sink is located far from the sensing field. Sensor nodes and data sink are all stationary after deployment.
- Sensor nodes are location–unaware that means they are not equipped with GPS or other similar equipment.
- Periodically the recently sensed data and information by all nodes are gathered and sent to the data sink after aggregation.
- Each sensor node is assigned a unique identifier (ID).
- The links are assumed to be symmetric.

Radio Model-Energy Equations

- Sensors decay their energy on transmission and receiving.
- If there are k bits to transmit over distance d
    - Transmission Energy Dissipation
        - Etx (k) =k* Eelec. + Etx_amp (k, d) (4.1)
        - Etx_amp (k, d) = k*d^2*Efs [9,10] (4.2)
- If sensor is receiving k bit
    - Receiving Energy Dissipation
        - Erx (k) = k* Eelec (4.3)

MEHEED is combinational work of first MEDC and second HEED. First MEDC was working on the parameters of residue energy $E_{residual}$ and range of communication and second HEED protocol considers three factors one of them is $Ch_{prob.}$ The proposed MEHEED will take first parameter same i.e. Ch_{prob} and second parameter will be $E_{residual}$ instead of S_{nbr}, the third factor is same for all three protocols here i.e. Range of communication. The idea to change the second parameter is; instead of considering previous calculated Snbr which was dependent on remaining energy of starting level, why not to consider $E_{residual}$ that have been recalculated after each iteration. Benefit of this idea will be that recent updated value i.e. $E_{residual}$ will also reflect energy detrainment of previous cluster heads. So decisions will be more accurate. MEHEED will works in two phases.

First phase will be of initialization and calculations phase is as like HEED. In first phase first of all sensors under the range are queued. On basis of this queue, Communication cost and $E_{residual}$ will be calculated. After that, Chprob will be calculated on basis of residual energy and predefined C_{prob} like of HEED see in equation 4.4.

$$CHprob = \max (Cprob \times Eresidual/Emax, pmin) \quad (4.4)$$

Second phase will decide the cluster head and the members under clusters. Second phase will decide which sensor will be cluster head. This decision firstly depends on Ch_{prob} after that this decision will depend on the $E_{residual}$ unlike HEED, in which second factor was S_{nbr}. If and sensor node is having Ch_{prob} is equal to one that it will be directly declared as cluster head and sensors under its queue will be cluster members for this. In case there is no sensor node under a range of communication have met first selection criteria then selection will be done according to MEDC rule i.e. on basis of remaining energy. The results have been shown that this idea has given more affective results to save network life.

Might be reader wish to know how CHprob can be equal to 1?

Here we want to give explanation of this as we said in equation 4.1CHprob = max (Cprob × Eresidual/Emax, pmin). Assume sensors may have their energy in range [0.0, 0.2]. 0.0 Joule is the minimum energy a sensor can have and 0.2 joule is the maximum. Here Cprob is initialized as 0.5. Pmin is assumed as 0.1. Eresidual is remaining energy of sensor say nodes i. assume node i is having 0.18. Emax will be calculated by average from network energy means calculating total energy of all sensor nodes and dividing by total no of sensor nodes. The fact is when sum will be calculated at that time some sensors might have energy at zero but they are part of network so their number will be calculated in network but energy in sum will be zero. Say we are having 50 nodes and let us say we had calculated sum that come out 4.5 Joule. Average energy will be assigned to Emax that will be (4.5/50=0.09).

Substituting the values in equation 4.1

CHprob = max (0.5 × 0.18/0.09, 0.1) =1

So we conclude that Chprob can be equal to 1; if any sensor node is not having value equal to one then MEDC will choose cluster heads.

4.2 Algorithm MEHEED

Two phase protocol

i- Sensor node

Rf- Range of frequency

v- Nodes under Rf

Qi-Queue of sensor i

Cprob- Predefined probability of each sensor

CHprob- Probability of being cluster head

Phase I

```
1.      For each sensor i
2.              Qi <-- v: v under of Rf
3.              Compute the communication cost of i after investing on Qi. And find the Eresidual
4.              CHprob  = max (Cprob × Eresidual/Emax, pmin)
```

Phase II

```
1. For each sensor i
2.      If (Chprobi == 1)
3.              cluster_head_declaration message
4.      else if
5.                      Advertise Epresent_i each j within Qi
6.                      Queue all incoming advertisements from sensors j into adv_Qi
7.                      Compare Epresent_i with each Epresent_j in adv_Qi
```

8. If (Epresent_i >= Epresent_j)
9. cluster_head_declaration message
10. else
11. find j in adv_Qi having Epresent_j >= Epresent_i
12. compare this Epresent_j with other sensors in adv_Qi and find the highest energy sensor let its r
13. do Chprobr = 1
14. do Chprobi = Chprobi *2

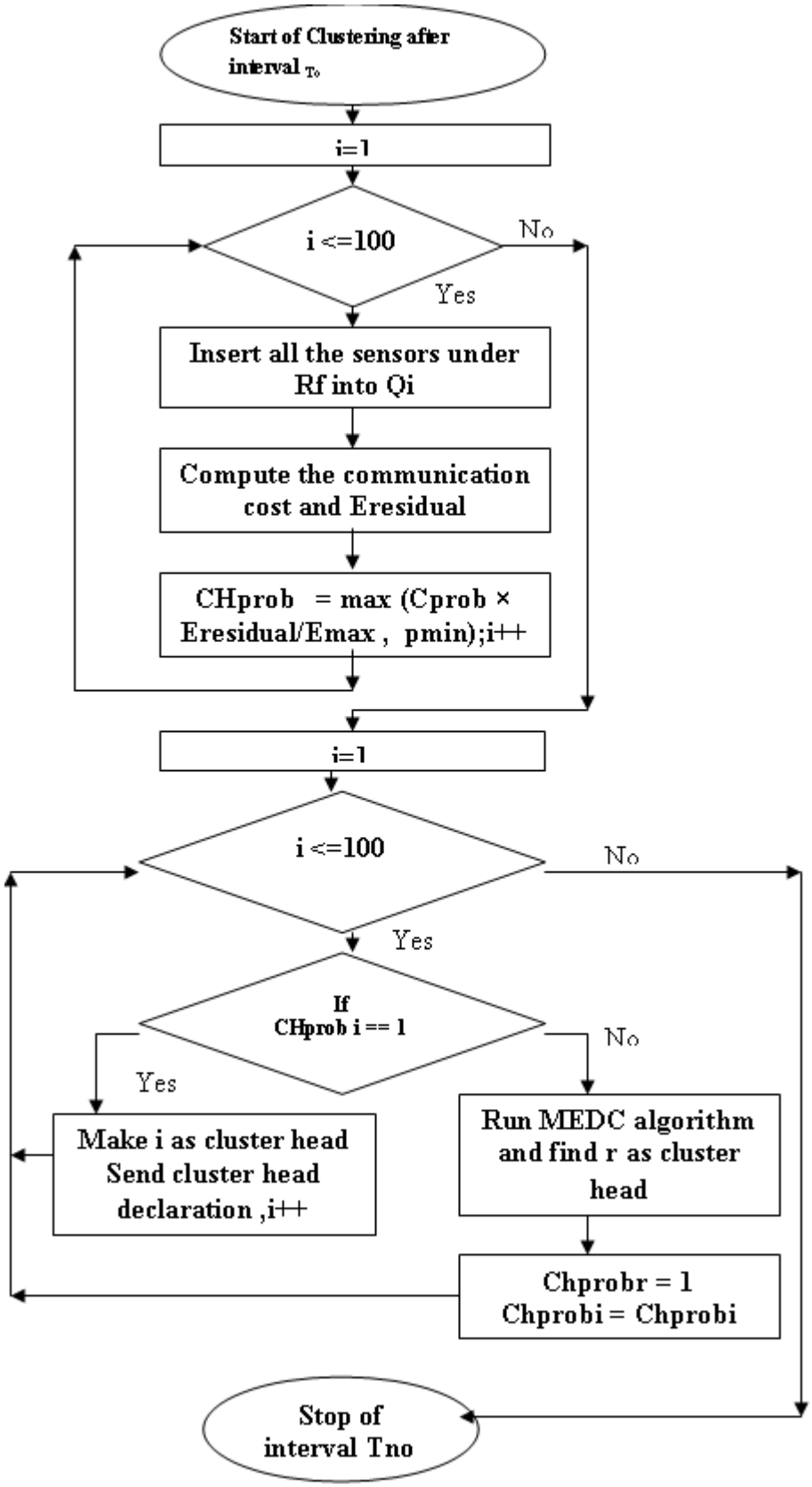
4.3 Experimental Evaluation

For simulation of MEHEED on MATLAB we had taken following parameters shown in Table 3. MEHEED results are shown from figure 15 to figure 22

Table 3- Simulation Parameters for MEHEED

Parameters	**Abbreviations**	**Values**	**Units**
Random field x axis	Xm	100	Meters
Random field y axis	Ym	100	Meters
Initial energy of sensor	Eo	0.05	Joule
Total number of sensor	N	100	
Transmission energy	Etx	50*1.E-12	Joule per bit
Receiving energy	Erx	50*1.E-12	Joule per bit
Free space energy	Efs	10*1.E-12	Joule per bit
Data aggregation energy	EDA	5*1.E-12	Joule per bit
Advertisement energy	Eadv	50*1.E-12	Joule per bit
Range of Communication	RC	20	Meters

4.4 Flow Chart



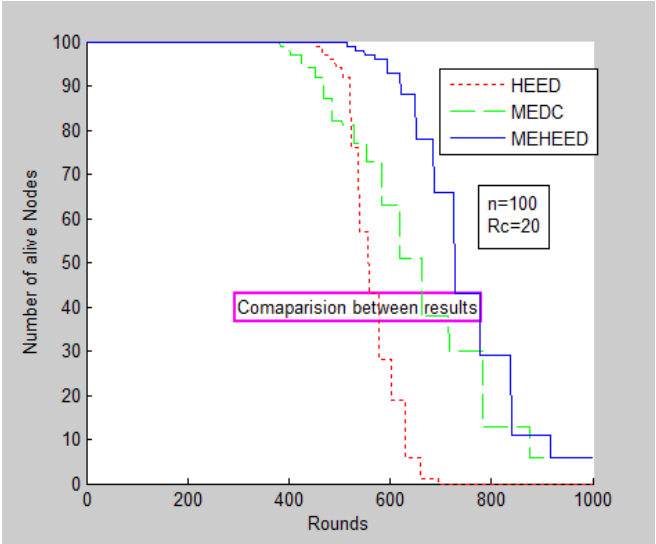


Figure 18. Comparative Results HEED, MEDC, MEHEED number of sensor=100 Rc=20

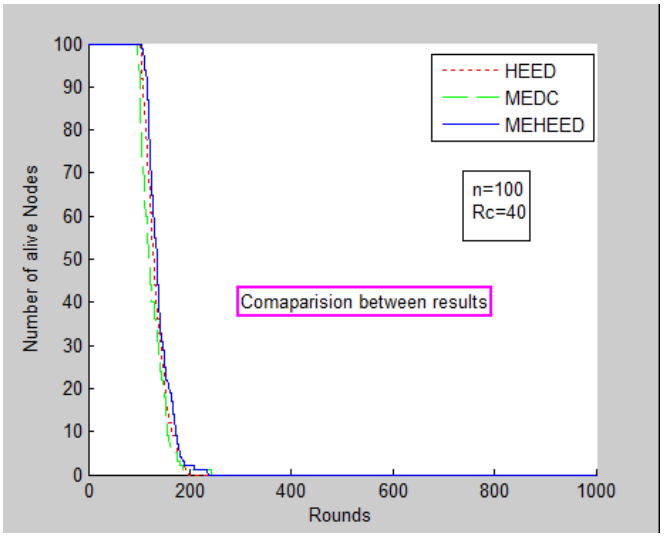


Figure 19. Comparative Results HEED, MEDC, MEHEED number of sensor=100 Rc=40

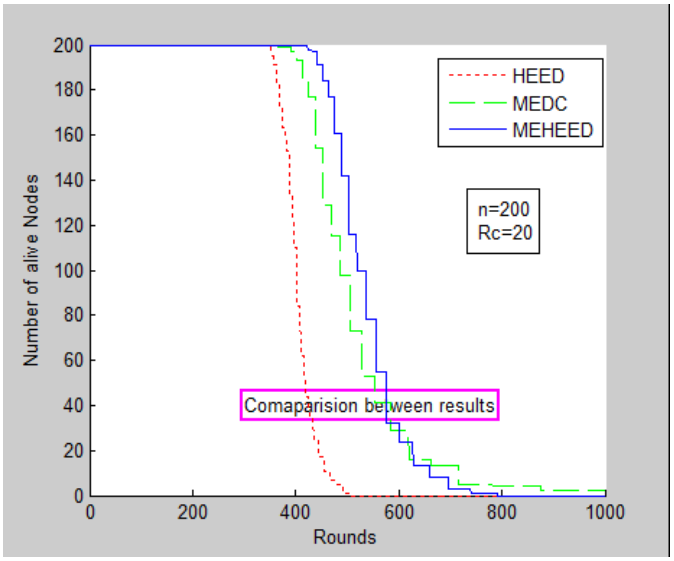


Figure 20. Comparative Results HEED, MEDC, MEHEED number of sensor=200 Rc=20

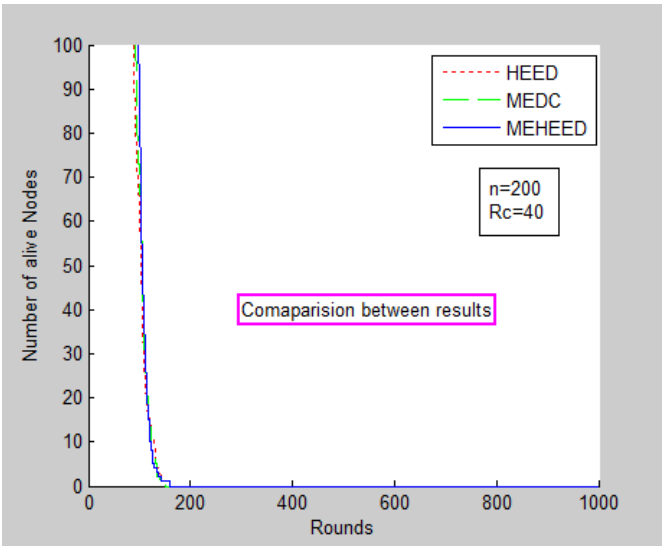


Figure 21. Comparative Results HEED, MEDC, MEHEED number of sensor=200 Rc=40.

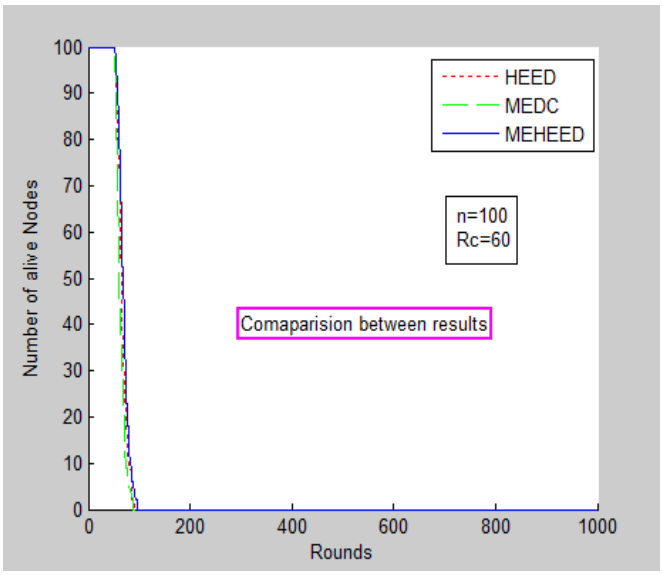


Figure 22. Comparative Results HEED, MEDC, MEHEED number of sensor=100 Rc=60.

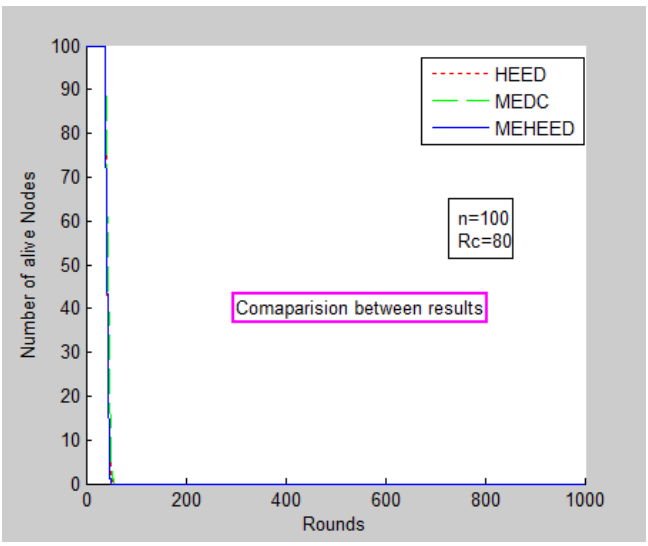


Figure 23. Comparative Results HEED, MEDC, MEHEED number of sensor=100 Rc=80.

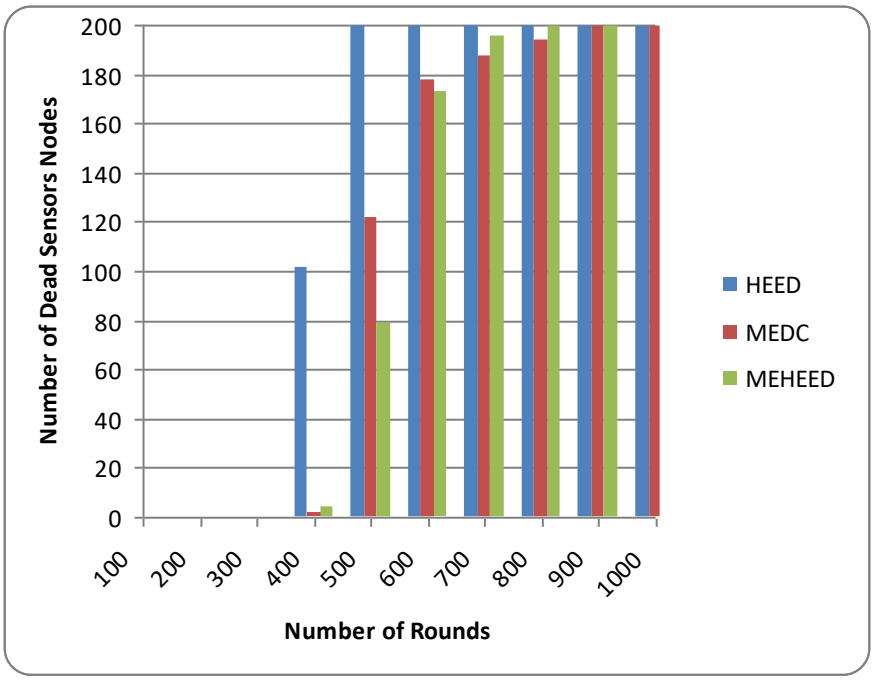


Figure 24. Comparison of No of dead sensors V/S Rounds when n=100 and Rc=20.

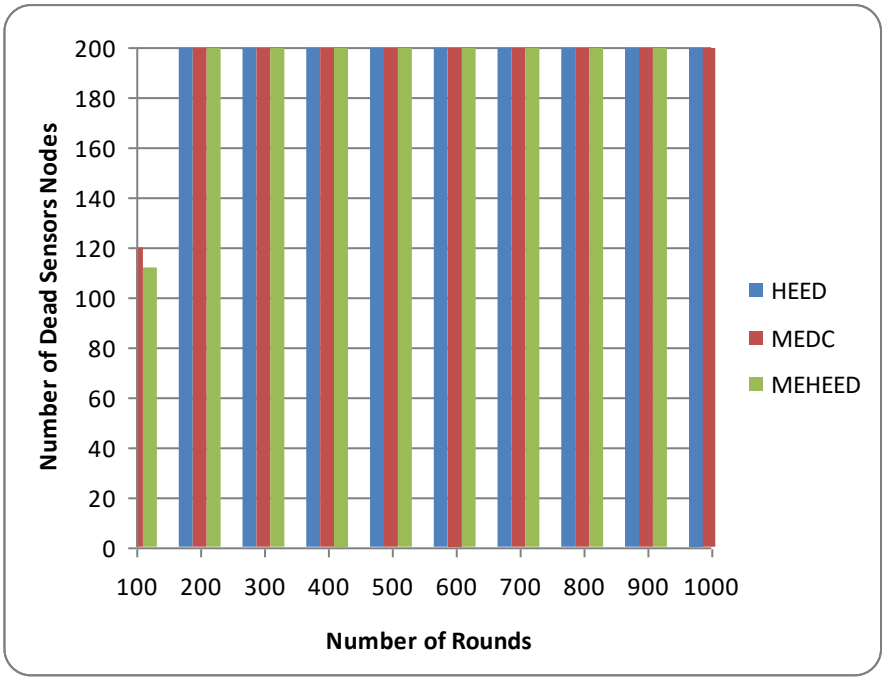


Figure 25. Comparison of No of dead sensors V/S Rounds when n=100 and Rc=40.

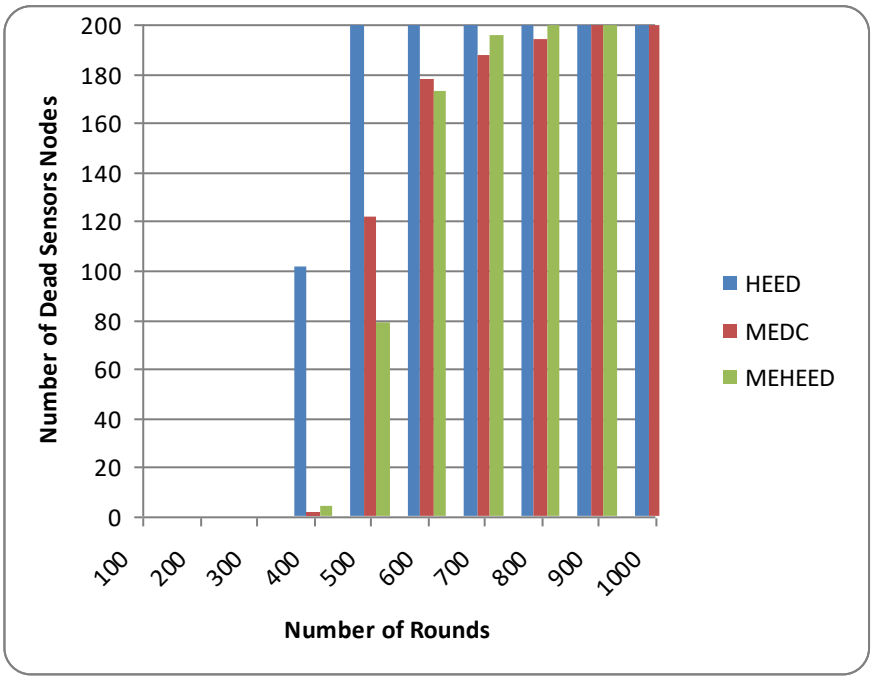


Figure 26. Comparison of No of dead sensors V/S Rounds when n=200 and Rc=20.

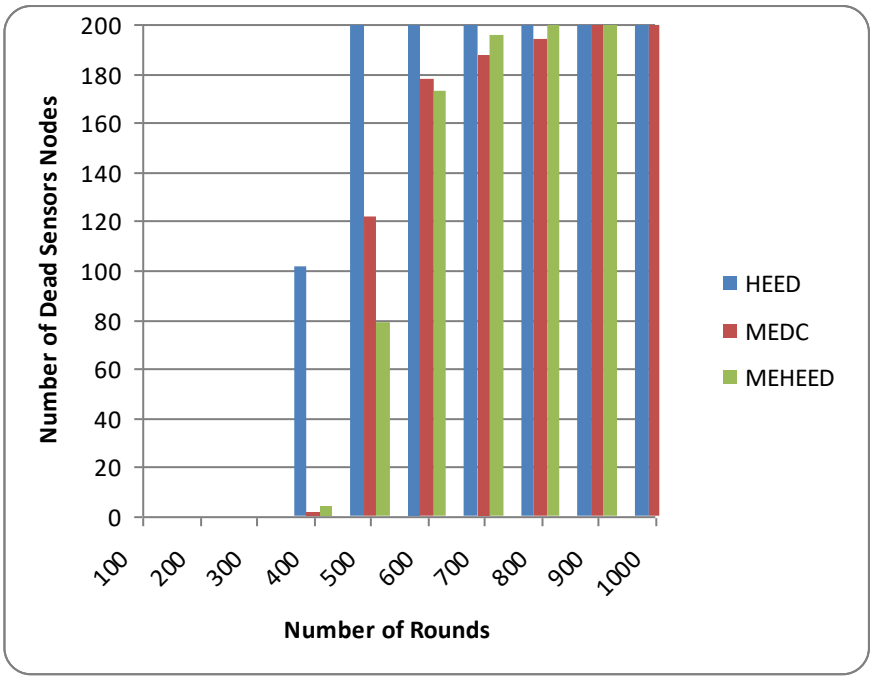


Figure 27. Comparison of No of dead sensors V/S Rounds when n=200 and Rc=40.

4.5 Results and Discussions.

MATLAB results for MEHEED are given in figure 15 to figure 22. Figure 15 is shown for comparative performance of MEHEED, MEDC, and HEED on parameter n=100 and range of communication is taken as 20. Performance is again measured in terms network life time. Network life time is measured as number of alive

nodes per round. In result graph Y axis represents alive nodes and X axis represents rounds. Figures 16, 17, 18 are results showing performance analysis of MEHEED, MEDC, HEED by varying values of n and Rc (Range of communication) n is varied on two values 100 and 200. Rc is also varied by two values one is 20 and another is 40. From different analysis we concluded that MEHEED perform better infect from MEDC also but as parameter are changed graph of MEHEED come closer to MEDC further close to performance of HEED. At n=200 and Rc=40 all three graphs overlap each other. Reason for this decrement in graph of MEHEED; is increased cost of communication. When we increase n from 100 to 200 or Rc from 20 to 40 then their will be more no of sensors under range of communication to each other. More sensors under range more advertisements means more cost of communication which result decrease in performance. Figures 19-22 are results of these three protocols for dead nodes calculation after rounds. Count values for dead nodes after 100 then 200 upto 1000 is taken for all three protocols; and graphs are plotted.

CHAPTER 5

CHANGE POINT DETECTION USING FIS

5.1 Introduction to FIS

FIS is tool of MATLAB. It is used to calculate results of fuzzy base. FIS use five steps

- Fuzzify Inputs
- Apply Fuzzy Operator
- Apply Implication Method
- Aggregate All Outputs
- De-fuzzify

Fuzzify Inputs

This is first step which take the inputs and calculate the degree to which they belong to each of the suitable fuzzy sets with the help of membership functions. We take inputs always in crisp form after which Fuzzy Logic Toolbox outputs a fuzzy degree of membership in the qualifying linguistic set.

Apply Fuzzy Operator

In Second step FIS apply operators. Two main operators are available in FIS one is AND another is OR. Fuzzyfied inputs are matched to antecedents of rules. If the antecedent of a given rule has more than one part, the fuzzy operator is applied to obtain number which represents the result of the antecedent for that rule. This number will then be applied to the output function. The input to the fuzzy operator is two or more membership values from fuzzyfied input variables. The output is a single truth value.

Apply Implication Method

After weighting assigned to each rule, the implication method is implemented. The input for the implication process is a single number given by the antecedent, and the output is a fuzzy set. Implication is implemented for each rule. Two built-in methods are supported, and they are the same functions.

Aggregate All Outputs

In Aggregation step fuzzy sets that are representing the outputs of each rule they are combined into a single fuzzy set. Decisions are based on the testing of all of the rules in an FIS, the rules must be combined in some manner in order to make a decision. Aggregation only occurs once for each output variable.

De-fuzzify

The input of Defuzzification step is a fuzzy set which is received from previous step (the aggregate output fuzzy set). Output of Defuzzification is a single number. However, the aggregate of a fuzzy set encompasses a range of output values, and so must be Defuzzified in order to resolve a single output value from the set.

5.2 Fire Detection scenario

Proposed Work-- Fire Detection

Three Input Variables

- Heat index
- Relative Humidity
- Carbon Mono-Oxide

One Output Variables

- Fire probability

5.3 MEDC with Change Point Detection Algorithm

Part 1 Procedure Cluster_formation (n)

```
1. For each IDi
2.      Counter =0
3. For each IDj within Rf of IDi
4.      Advertise Eresidual_i
5. For each IDi
6.      Put all incoming advertisements from sensors j into Qi
7. For each IDi
8.      While Qi is not empty
9           If Eresidual_i <= Eresidual_j
10.             Send ok message to IDj
11.             Counter = 1
12.         Else
13.             Delete this advertisement from queue
14. For each IDi
15.     If counter =0
16.         Send cluster_head_declaration message to IDj within Rf
```

Part 2 Procedure Change_point_detection (n)

```
1. For each IDi
2.      If counter =0
3.              Collect the information from sensors IDj from which OK message received.
4.              Calculate mean of sensed information.
5.              Input the average values in FIS.
6.              Apply fuzzy rules and calculate Pr
7.              If Pr >=0.5
8.                  Report to base station for change point detection.
9.              else
10.                 Cluster head will remain silent. Aggregated information need not to send
```

We have simulated 5 real data sets value on our proposed system, the results are given in following table. On the basis of result obtained we have decided that Pr value should be 0.5 or greater as keeping it less than 0.5 number of false detection are more.

Table 4- fire Detection using MEDC

Pr Values	Total no: of events inputted	No: of event detected	False Detection	Event skipped
0.2	10	10	4	Nil
0.4	10	8	2	Nil
0.5	10	5	Nil	1
0.6	10	4	Nil	3
0.8	10	2	Nil	5

5.4 Experimental Evaluation

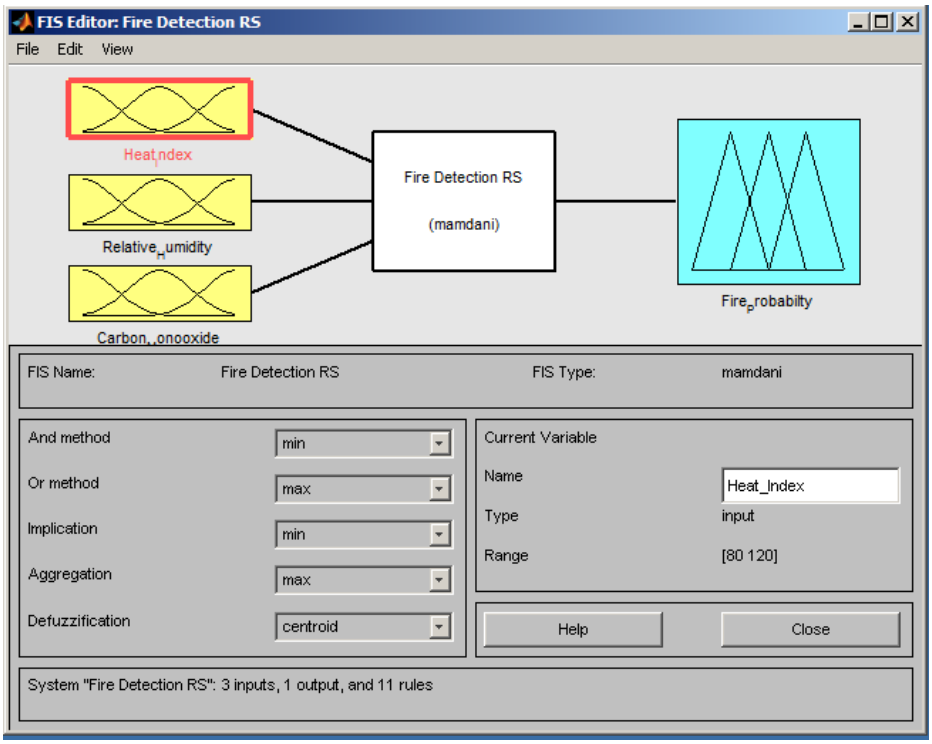


Figure 23. MATLAB Implementation Snapshot for fire detection

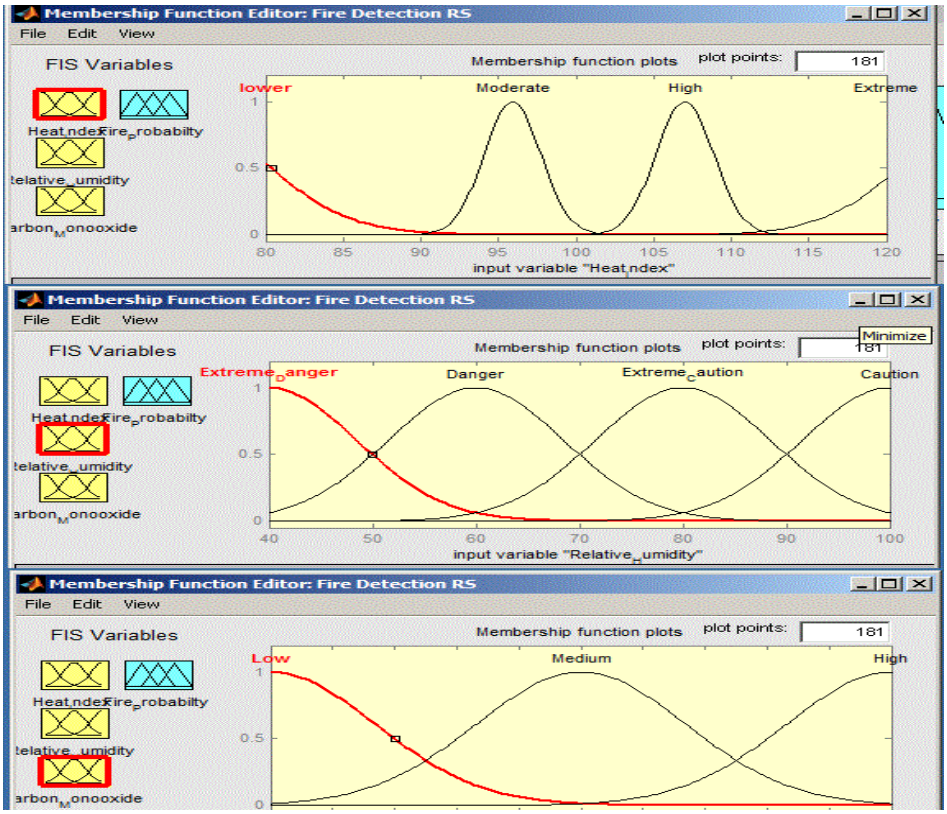


Figure 24. Snapshot for input variables

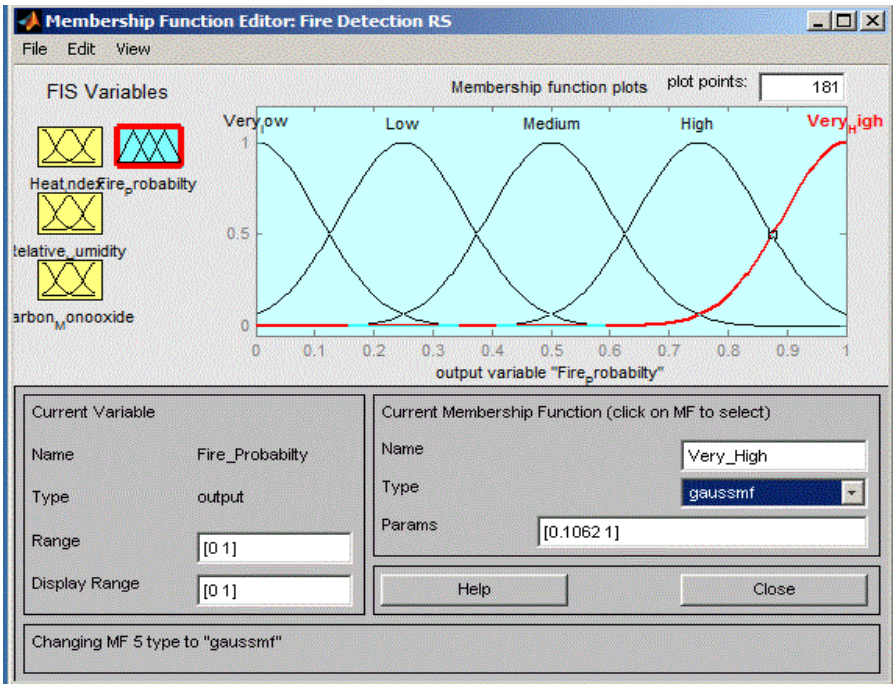


Figure 25. Snapshot for membership function of output variable

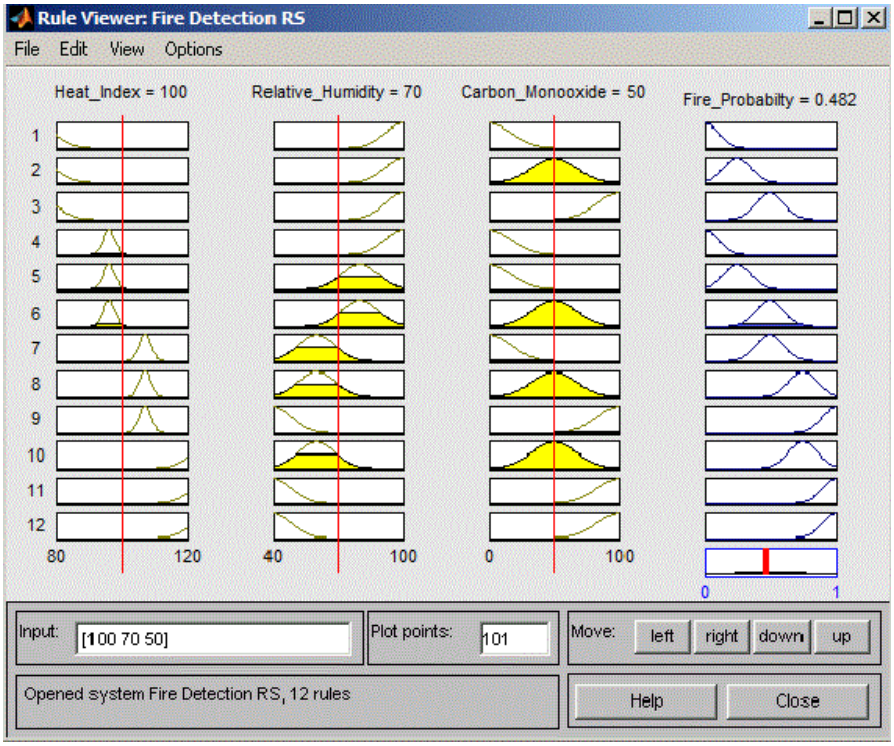


Figure 26. Snapshot for rule viewer

Table 5- Value of output probability according to different values of input variables

Input Variables			Output Variable
Heat Index ˚F	Relative Humidity (%)	Carbon Mono-oxide(ppm)	Fire Probability
85.54	82.3	48.8	0.281
100	70	50	0.482
90.8	59.9	64.5	0.498
110	40	60	0.724
120	50	90	0.85

5.5 Results and discussions

FIS take inputs in crisp form and give output also in crisp form. But this mapping is totally based on fuzzy rules in turn also on membership functions. Here in fire detection FIS we had mapped three input functions to one output function shown in figure 23. Three input variables heat index, relative humidity, carbon monoxide are inputted with crisp values membership functions are shown in figure 24. These values are fuzzyfied, mapped to fuzzy output with the help of rules and operators. Membership function for output variable is shown in figure 25. Fuzzy output is then Defuzzified to get crisp value in result form. Here this outputted value is represented as fire probability. Fire probability varied as according to three values.

CHAPTER 6
CONCLUSION AND FUTURE DISCUSSIONS

6.1 Conclusion

In this thesis we have developed two clustering protocols MEDC and MEHEED for wireless sensor nodes that is capable of addressing the power consumption requirements of wireless sensor networks. These clustering protocols had shown significant improvement of approximate 33% enhancement in network life time. By utilizing these protocols, we have also developed change point detections approach that is able to support change point detection in fire application without sacrificing efficiency. These protocols have been validated through the simulation in MATLAB with different scenario.

The protocols presented in this thesis have to improved life time of wireless sensor networks and also contributed a combined solution that will work for clustering and change point detection. On maximum exhausted network parameters for all HEED, MEDC, and MEHEED are comparable but when we increase the number of sensors and decrease the range of communication, the communication cost get increased therefore performance get decreased.

6.2 Future Work

In future the information fusion could be done with clustering protocols with various distributions of sensor nodes. Other change point detection techniques in literature can be tried with proposed clustering protocols. Chargeable sensors can be taken as further challenge.

6.3 List of publications

1. Urvashi Chugh, Yashwant Singh, M.V. Ramana Murthy, “Change Point Detection in the midst of Mutual Exclusive Distributive Clustering Protocol” Wulfenia Journal, Klagenfurt, Austria, ISSN 1561-882X, pp 311-319, Vol .22 No.10, October, 2015. (Journal SCI Indexed)
2. Yashwant Singh, Urvashi Chugh, “Clustering, Information Fusion and Event Detection in Wireless Sensor Networks: A Review” in IEEE Conference 9th INDIACom, March 11-13, 2015, BVICAM New Delhi, pp288-233, 2015. (Conference, IEEE)
3. Yashwant Singh, Urvashi Chugh, M.V. Ramana Murthy, “Information Fusion and Change Point Detection in Mutual Exclusive Distributive Clustering” in Elsevier Procedia Computer Science; proceedings International Conference on Communication, Management and Information Technology (ICCMIT 2015) Vol. 65 pp 592-600.(Journal, Scopus)
4. Urvashi Chugh, Yashwant Singh, M.V. Ramana Murthy, “Comparative Analysis of HEED, MEDC, MEHEED” in World Congress on Engineering and Computer Science October, 2015 (accepted In process) [IET INSPEC, Thomson Reuters ,Engineering Information [Ei Compendex, DBLP, Elsevier's Scopus]. (Conference, Scopus, DBLP)
5. Yashwant Singh, Urvashi Chugh (2014). Mutual Exclusive Distributive Clustering (MEDC) Protocol for Wireless Sensor Networks. International Journal of Sensors, Wireless Communications and Control Bentham Science Press, 3 (2), 101-107.[Indexed in J-Gate.]. (Journal)

6. Yashwant Singh, Urvashi Chugh (2014). MEHEED: Mutual Exclusive Hybrid Energy Efficient Distributed Clustering in Wireless Sensor Networks. Proceedings of the ELSEVIER ERCICA Bangalore, India : August 1-2, 2014, pp 540-545.[Indexed in DBLP].(Conference, Elsevier)
7. Yashwant Singh, Suman Saha, Urvashi Chugh and Chhavi Gupta, "Distributed Event Detection in Wireless Sensor Networks for Forest Fires", IEEE UKSim-AMSS 15th International Conference on Modelling and Simulation, Cambridge University, Emmanuel College, 10-12, pp 634-640, April 2013 ISBN 978-0-7695-4994-1. [Indexed in SCOPUS and DBLP]. (Conference, IEEE)
8. Yashwant Singh, Urvashi Chugh, Amit Chugh (2012), Self Healing Routing in Autonomic Wireless Sensor Networks, Proceedings of the International Conference on Advance Computing and Communication Technologies, November 12, pp.308-312. (Conference)

6.4 Under Communication

Urvashi Chugh, Yashwant Singh, "Performance Analysis of MEDC", 2016 the 2nd International Conference on Information Technology (ICIT 2016), Melbourne, Australia, March 3-4, 2016 (Accepted)

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